STEEP GRADIENTS

HENRY HANDYSIDE

A TREATISE

ON AN

IMPROVED METHOD

FOR

OVERCOMING STEEP GRADIENTS ON RAILWAYS,

WHEREBY ANY ORDINARY LOCOMOTIVE,
CAPABLE OF HAULING A GIVEN LOAD UP A GRADIENT OF 1 IN 80,
CAN TAKE THE SAME

Up 1 in 8.

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STEEP GRADIENTS ON RAILWAYS.

1. VERY numerous and varied have been the means adopted for overcoming steep gradients on railways, and several of them have been successful in a commercial point of view, especially where the gradient was confined to the attainment of perhaps only one special elevation, which circumstances compelled the line to attain within a given distance, but still none of them have been of a sufficiently cheap and effective nature to recommend their adoption for general use on any line taken through a difficult and hilly country, and where the said steep gradients would be frequently recurring.

2. It is with the view of supplying this great commercial want that the author has ventured to advance a system of his own, which he hopes will be found to fulfil the numerous advantages he has claimed for it.

3. It is hoped that this paper will fully explain what the author calls his system ; many will feel inclined to smile at its apparent simplicity, and probably doubt its power to fulfil the great saving and other advantages claimed for it.

4. But if it can be shown that the new system, while sustaining a diminution of speed, achieves a counterbalancing advantage in cost of construction, and that as large a proportion of weight can be transported as is now accomplished by the general means in ordinary use, then it is hoped it will recommend itself to the notice of engineering circles, and at least receive an impartial consideration before being condemned.

5. This system may be considered as a new one, for the construction and future working of railways still to be carried out, at the same time of such a nature, as in no way to interfere with the permanent way or rolling stock of existing lines.

6. When this important point has been fully proved, it is hoped to enlist the good-will of all railway companies and manufacturing railway engineers in particular—for this system

does not seek to denounce any construction of locomotive or any gauge, but to place within the reach of all a certain simple arrangement of well-known forces, by which their effective power will be more economically utilized.

7. Little or no opposition is anticipated from the professional world on the ground of the impracticability of the system; but all proposed changes must claim some special advantages before they can be recommended by professional men to the capitalist or company who may be embarking largely in the construction of new lines of railway.

8. Hitherto few lines have been a remunerative commercial success; that is, few lines have paid an adequate percentage on the money invested in their construction.

9. The want of this great desideratum, as proved by most existing railways, is having its influence in keeping capital from being invested largely in all parts of the world, where the extension of the railway system would bring into occupation large tracts of available country, which from their very extent must necessarily be sparsely occupied at first, but from that very extent offering large inducements and advantages to the pioneer of civilization.

10. Another great mission for railways to perform is the cheap haulage of the mineral products of any country; and unless a system of railway construction very much cheaper than the present one is adopted, many rich mineral deposits will remain unworked, or if worked will make the pecuniary results most unsatisfactory to those who have ventured their capital in the speculation.

11. The author having resided in New Zealand for many years, could not fail to take a lively interest in the future prospects of the most truly English colony which Britain possesses.

12. With a climate which is unrivalled, with the well-known fertility of its soil and its almost inexhaustible but undeveloped mineral wealth, it must at some future day become the Britain of the South.

13. Like most new countries peopled by the Anglo-Saxon race, it has not been slow to keep pace with the times, and has

consequently long accepted a railway system as the only method of developing the interior of the country.

14. With great natural resources, its borrowing powers have been proportionally great, and several millions have been borrowed, and are being spent in carrying out the public works policy, the principal feature of which is the commencement of a complete railway system for New Zealand.

15. The cost of several small portions, which have been completed, shows clearly that to complete the whole proposed system at that rate would require a sum which the public creditor could not recognize as bearing a just proportion to the probable receipts for many years to come, and that consequently, unless a much cheaper system of railway construction could be adopted, the colony will find itself in a few years with several isolated portions of railway, and without any immediate prospect of being able to raise the money to complete the system, which by traversing the middle island would place its mineral wealth in connection with places of shipment.

16. Although the foregoing remarks are especially relating to New Zealand, it will readily be admitted that the same remarks are equally applicable to all parts of the world where the construction of railways may be contemplated.

17. Thus, there may be certain localities in many countries which it might be very desirable to place in communication with water-carriage, or other established lines of railway, but from the distance or difficult nature of the intervening country they continue to remain in their isolated condition.

18. Holding this opinion, and feeling convinced that the present rate of railway construction (principally entailed on it by the requirements of a high rate of speed, even up the ruling gradients) was too costly for thinly-populated countries, where speed was not indispensable, the author turned his attention to study carefully the causes which lead to the present costly style of permanent way.

19. Having examined the much-debated question of "gauge," which by some engineers has been considered to contain the whole secret of the future economical construction and working of railways, the author was convinced that some further im-

provement and reduction of first cost would be required before the railway system could or would be adopted in many places.

20. There is no doubt that the investigations and reports of such able engineers as Mr. Carl Phil, of Norway, and Mr. Robert Fairlie, are doing a great deal to throw light on this important and much-contested point, and we have now numerous practical proofs in operation, from which we may be able to determine which "*gauge*" will secure the maximum of efficiency with the minimum of cost.

21. This great question of "*gauge*" being thus in process of practical proof, it would be presumptuous and useless on the author's part to offer his opinion on it, but there is another portion of railway construction to which engineers have of late devoted comparatively little attention, and one which it shall be endeavoured to prove, exercises a much greater influence on the first cost of all railways than "*gauge*," it is "*a cheap and effective mode of overcoming steep gradients.*"

22. The author does not mean, of course, to ignore the very numerous steep gradients which as special instances have been successfully overcome, such as the Mont Cenis, the Mont Rigi, and on the São Paulo Railway in Brazil, but the author believes that these would be found far too costly to be adopted as a general system for taking a long line of railway through an undulating or hilly country, where steep gradients would be of frequent occurrence.

23. Speed has hitherto been considered essential on all our English lines, chiefly owing to the demands of passenger and mail traffic, so that steep gradients were thought quite inadmissible, and hence the costly but splendid triumphs of engineering skill with which our lines abound, in the shape of bridges, viaducts, tunnels, &c., all rendered necessary from the fact that a "*certain given gradient shall not be exceeded.*"

24. It is this arbitrary stipulation which, in the author's opinion, causes the enormous cost of many railways; and we hear of certain lines having cost so much, as an average per mile for the whole, whereas in reality the bulk of the money has been expended on certain short but difficult portions.

25. The author hopes that his new system, which will now

be explained, will fulfil all the requirements of the case, and enable the engineer to advance boldly into the most difficult country with the conviction that any distance of the most hilly country may be traversed at a greatly reduced cost per mile for the construction of the permanent way, and with a far larger effective result from "*any locomotive employed, using the new system*," than can be obtained from it under the ordinary system of traction.

26. In order that the whole subject may be fully handled, it has been classed under fifteen heads, which are:—

1st. Saving in first cost of survey.

2nd. Saving on embankments.

3rd. Saving on face cuttings.

4th. Saving in the length of tunnels.

5th. Saving in the length and height of viaducts.

6th. Materially shortening all lines which have high land between their extremities.

7th. A corresponding saving in length of rails.

8th. Any locomotive capable of hauling a given weight up a gradient of say 1 in 50 to be capable of hauling the same load up 1 in 10 or even 1 in 8.

9th. A much lighter class of locomotive necessary.

10th. A corresponding reduction in weight of rails.

11th. Simplicity of construction, inexpensive, and not easily deranged.

12th. Less friction and tear and wear on all steep gradients, of say 1 in 10, than on the generality of gradients now in ordinary use.

13th. No break of gauge necessary, and applicable to any gauge.

14th. Especially applicable to tramways, which as feeder lines will often penetrate into hilly districts.

15th. The carrying power along the whole line not limited by the frequent occurrence of steep gradients.

27. It is now proposed to state briefly the *modus operandi* of the new system, and then proceed to show how, in the author's opinion, this system will produce the numerous advantages claimed for it.

28. With sufficient steam power, the "*tractive power*" of all locomotives depends entirely on the "*weight*" which can be thrown on the "*driving-wheels*," and consequently the greater the number of these wheels, which are coupled together, the greater will be the friction or resistance obtained from the several points of contact between the surface of the rails and the tires of the driving-wheels.

29. Mr. J. S. Isaac, as far back as 1858, stated before the Institute of Civil Engineers, with reference to the working of steep gradients in America, "that locomotives did take loads greater than themselves up 1 in 10."

30. Which showed that the weight of the engine was four and three-quarter times the resistance of gravity and the resistance of the load.

31. This proportion of adhesive or frictional force between the wheels of the locomotive and the surface of the rails is by most engineers considered excessive, and not to be depended upon in all weathers and conditions of the rails, without the frequent use of sharp sand, which is in any case objectionable from its destructive qualities.

32. At the same time, on this question, Mr. Bidder, V.P., made the following remark:—

33. "As a mechanical question, there was no difficulty in apportioning the power of the engine to the amount of adhesion required to traverse any particular gradient. He thought that an available tractive force of one-fourth of the weight of the engine ought to be provided; but that they were not justified in reckoning upon more than one-sixth under all circumstances."

34. Thus it appears clear that the effective power of all ordinary locomotives must be limited by their "*weight*," and not by their "*steam power*," for nearly all modern locomotives have far more steam power than is necessary to overcome the tractive resistance of their driving-wheels.

35. This steam power can be still further augmented to a far greater extent than is now necessary, by the improvement in the construction and material of which the boilers are made, thereby enabling them to sustain a far greater pressure of steam.

36. That highly-scientific engineers have for many years

viewed with disfavour this inclination to obtain tractive force by adding to the weight of the locomotive may be gathered from the remark of Mr. Fell, made before the Institute of Civil Engineers in 1867:—

37. "There was nothing more shocking than the idea of adding to the weight of the machine, not to get the requisite power, but to get the requisite adhesion; to add to the weight of an engine, in order that a small portion of the weight might be available in getting up an incline, was clearly most objectionable; and he thought that anyone who helped to get rid of this stigma upon mechanical engineering deserved the thanks of the profession."

38. The author therefore proposes to utilize all the power that can be obtained from the steam pressure, and devote it entirely to hauling the train, without the engine, up steep inclines of say 1 in 10; for although the principle will hold good up to 1 in 8, it may be found in practice more economical not to approach the limit too closely.

39. In other words, it is proposed to transform the locomotive into a stationary engine "*whenever*" and "*wherever*" it may be required, which in that position will be enabled to concentrate all its power in drawing up the train of carriages or wagons.

40. That some engineers of high standing look with considerable favour on what is known as the "*rope system*," we may infer from the remark made by Mr. Bramwell in 1870, before the Institute of Civil Engineers:—

41. "That it had been asserted that an engine could be constructed capable of taking its own weight and 145 tons of load up an incline of 1 in 15; but it was said that the engine to be employed to do this must weigh 68 tons, or nearly half the load it could haul behind it. Now having regard to the fact of the enormous percentage of useless weight such an engine would bear to the load it could draw, he thought that even if there were a considerable loss of power and difficulty attendant upon the rope system, nevertheless that system was preferable to the use of a machine which weighed 50 per cent. of the useful load it could move."

42. Under the present system of rope traction the "*loss of*

power" to which Mr. Bramwell alludes must be very great indeed, caused by the length and weight of the rope, and the immense friction it has to sustain in passing over hundreds of iron sheeves, placed at every conceivable angle on account of the tortuous nature of the incline.

43. On the São Paulo inclines in Brazil, one of the latest instances of the application of rope traction, this loss of power is very evident from the fact—

44. " That ropes are tested to 35 tons breaking strain, the maximum working load, as shown by the dynometer, being from 4 tons to 4½ tons. Their duration is about two years."

45. So short a life as two years clearly proves that the ropes must sustain immense friction, and in spite of its immense strength one of these ropes broke in 1869.

46. The general details of the new system may be understood from the following description, and relates principally to one arrangement of parts, to be applied to almost any ordinary construction of locomotive and railway carriage or wagon, whereby the safe and easy ascent of trains up steep gradients is accomplished, and their passage round sharp curves is facilitated.

47. According to the new system the locomotive engine is coupled to the train by a steel chain, which is wound round a drum mounted in the framing of the engine.

48. The axis or shaft of this drum works horizontally in bearings fixed in the main framing of the engine, and is rotated, direct or with more advantage by gearing, from a separate pair of cylinders, distinct from the usual cylinders which drive the locomotive.

49. The drum need not exceed 2 feet in width, and its barrel 1 foot in diameter, with an outside diameter for the cheeks of 3 feet: this size will accommodate an ample length of steel chain to fulfil all the requirements of the system.

50. The chain to be of about ¾ inch diameter, round steel, slightly tempered, and the required length need not exceed half a ton.

51. On each side of the engine framing, and also on each side of one or more carriages or wagons of the train, there are suspended one or more self-acting gripping struts, which, when

let down on the rails by the driver or other person in charge of the train, will firmly grip the sides of the rails and hold the engine or train stationary.

52. The gripping portion of these struts are made of steel, having their inner surfaces hardened and roughened, so that the possibility of slipping is entirely obviated, and as the *sides* of the rails are thus being grasped by roughened surfaces of hardened steel, the *top* of the rail will not sustain any injury.

53. On arriving at the foot of a steep incline, the engineer will release the hauling-drum, and may without stopping the engine run it up the gradient to any desired distance.

54. The driver having released the struts, they come into contact with the rails, and on the engine being stopped and attempting the least retrograde motion, they firmly grasp the rails, and maintain the engine in its place.

55. The hauling-drum is now started, and the chain draws the train close up to the engine.

56. The struts on the train are now allowed to come into action, and firmly hold the train in its place, or these struts may have been released before commencing the ascent of the incline, by which means all possibility of accident from the breaking of the chain, or other cause, is entirely prevented.

57. This automatic action of the struts must recommend itself as a great advantage when it is considered that at present the usual break appliances are entirely dependent on the vigilance and presence of mind of the person in charge of the train.

58. To prevent all danger of over-winding, a simple automatic arrangement is attached to the engine, by which the steam is cut off from the cylinders which drive the hauling-drum the moment the train touches the engine.

59. The operation which has now been described will be repeated as often as required, until the whole of the gradient has been surmounted.

60. The author would particularly call attention to this feature of his system, that no particular length of gradient has any influence on its success, neither is it *essential* that the length of the chain should bear any relative proportion to the length of the gradient.

61. On level sections, or on comparatively light gradients, the locomotive acts precisely as an ordinary locomotive engine.

62. It is obvious that this arrangement of hauling-drum and separate winding-engine will also be found most serviceable in facilitating the hauling of heavy trains by light locomotives round sharp curves.

63. In order to prevent exposure and consequent injury to the tubes and fire-box roof, by reason of the displacement of the water-level when ascending or descending steep inclines, there are provided two steam domes, or chambers, on the top of the boiler near the ends thereof, and these are connected by an equalizing pipe. The steam for supplying the cylinders of the engine and those of the winding-drum is taken from the domes in the usual manner.

64. Having thus fully described the principles of the new system, and the means to be employed for carrying it out, we will now proceed to explain all the numerous advantages claimed for it, as stated under the foregoing fifteen heads.

65. Many who read this description will at once think that there is comparatively little of it new, and certainly the use of a rope and a stationary engine is not novel, but the idea of converting the locomotive itself into a stationary engine has never been practically tried on any railway, neither has it been brought forward in a sufficiently practical form to command the attention of the engineering world.

66. The only instance which the author has heard of, which may be considered to approach in similarity to his system, was alluded to by Mr. W. Lloyd, in 1867, before the Institute of Civil Engineers:—

67. " As having been used by him as a temporary expedient for overcoming a gradient of 1 in 12, in Chili. He converted an ordinary locomotive into a stationary engine, permanently fixing it on the top of the incline, and with a rope made to wind up heavy trains; this he worked successfully for four years."

68. But of course this expedient laboured under the usual extra expense of guide-rollers and great length of rope, and consequently loss of power.

69. If ever thought of before, the author's system may have been shelved from the fact that speed has hitherto been the first requirement, and consequently steep gradients were not admissible.

70. It is hoped, however, to be able to prove, that with this new system a fair average speed may be maintained, with other and great commercial advantages, to compensate for any loss of time which may result from its adoption.

1. *Saving in First Cost of Survey.*

71. It is proposed to prove this one point by the aid of only one example.

72. Suppose it is required to take a line of railway from the point A to B (Fig. 5), the distance being one mile, and the point B 528 feet above the level of A, thus giving a gradient of 1 in 10.

73. For the ordinary requirements of railway traffic probably a gradient of 1 in 80 would be made; thus, on leaving the point A the line would require to be taken away from the direct course, perhaps a zigzag, in order to obtain a length of eight miles, which "*length*" could alone give the gradient of 1 in 80.

74. Thus it must appear that instead of surveying one mile, eight will have to be done, and consequently in this and similar instances the new system will effect a saving of seven-eighths of survey cost.

75. Although only this one example has been taken for the sake of illustration, it must be admitted that very many similar instances will occur on almost every line of railway which is taken through a broken line of country, and where often a very long and comparatively easy line had to be abandoned on account of one or more sudden rises, which it would have been too costly to overcome, with any of the known special methods now in use, some of which require such a total alteration in the construction of the locomotive employed, rendering it partially or altogether useless on the level portions of the line.

76. In support of this hypothesis the Derbyshire High Peak

line may be taken as an example, where the first selected and shortest line had to be abandoned on account of one steep gradient, and a circuitous and much more expensive line selected.

77. The author may be accused of having selected a most exceptional case of a zigzag in support of his argument. Such, however, has been done; and although few engineers would recommend this plan, still the requirement remains unaltered, and whatever may be the course of the lesser gradient it must perform the distance specified to attain the given height of 528 feet, with the given gradient of 1 in 80.

78. If this example is admitted to be correct in principle, it may be taken as the chief axiom to most of the following propositions.

2. *Saving on Embankments.*

79. To show the proportionate cost of embankments as required for the usual system and those to be adopted in the new, we will take an ordinary case of an elevation of 33 feet requiring to be banked up to, with a gradient of 1 in 80.

80. The point A (Fig. 6) being 33 feet above the level of the starting point of the embankment at B, must be distant 2640 feet, or half a mile, to ensure a gradient of 1 in 80.

81. For an ordinary double line of rails, this would take about 6257 cubic yards of filling, which at 1*s.* 6*d.* would cost 474*l.* 5*s.* 6*d.*

82. By adopting the new system the line might proceed along nearly level ground till it came to the point C, which is only 330 feet from A, which distance will give a gradient of 1 in 10 to A.

83. This short embankment will contain only about 782 cubic yards of filling, which at the same price will cost 58*l.* 13*s.*, thereby effecting a saving of 415*l.* 12*s.* 6*d.* in half a mile, which makes the cost of the earthwork on the new system about one-eighth of the cost of the other.

84. Most engineers will admit that this example is not exaggerated and of common occurrence on all lines, and it will only become a question of mere calculation how often it

may be expedient to adopt this new system by using the steeper gradients.

85. In many cases it may be both difficult and expensive to obtain the required material for making up a long piece of embankment.

3. *Saving on Face Cuttings.*

86. The proving of this saving is nearly identical with the last.

87. The face of a terrace at A (Fig. 7) is 33 feet high, to obtain a gradient of 1 in 10 the excavation will be commenced at B, which is 165 feet from A, and with the material excavated carried out to C, also 165 feet from A, will give the desired gradient.

88. But if a gradient of 1 in 80 must be obtained, then the excavation and filling must be carried out 1320 feet on either side of A, and thus it is proved that the steeper gradient will save seven-eighths of the cost of the lesser gradient.

4. *Saving in the Length of Tunnels.*

89. Tunnels are one of the most expensive works in connection with railway construction, and are consequently only resorted to when all other means have failed to obtain a practicable and cheaper passage for the line over the elevation which forms the obstruction.

90. It is therefore evident that when a tunnel has been determined on, the point where the ground has to be pierced is taken as high up the side of the mountain as the ruling gradients on the line will admit.

91. This is evident from the fact that the tunnel must become shorter as it approaches the summit of the mountain.

92. Fig. 8 represents the case of a level tunnel passing through a mountain from A to B, and that, owing to the ruling gradients, these two points are the highest that can be obtained.

93. By employing the new system, and thereby adopting a gradient of 1 in 10 for a short distance at either end before commencing the tunnel, a much greater elevation will be obtained, and hence the result of a clear saving of length of tunnel as shown at C D.

94. The author inserts the following printed data, in confirmation of his assertion respecting the excessive cost of tunnelling:

95. "The Italian Commissioners who reported on the experiments on the Mont Cenis, admitted a saving of 104,800,000 francs out of 133,800,000 francs, in favour of a summit line as compared with a tunnel."

96. But owing to the great uncertainty of all works connected with the latter method, this estimate might be far exceeded.

97. Fig. 9 represents the case of a railway having to be taken from one valley to an adjoining one, their altitudes being different.

98. We shall suppose that owing to the configuration of the ground or special obstacles, B, the desired point, is the highest which can be obtained in the lower valley, and that this point is in the relative position to the point A in the upper valley, giving a gradient of 1 in 10.

99. By the adoption of the new system this gradient can be easily worked, but under the present system the line would require to be carried on for several miles to attain the required altitude C, so as to obtain the gradient of 1 in 80, and even when reached the position may not be as favourable for a tunnel as the one abandoned.

100. Although only these two simple illustrations have been brought forward, it must be apparent that they fully represent a great saving, and instances of considerable difficulty easily overcome.

101. It is also expected to be a great advantage to possess the means whereby the engineer will be comparatively free to select the shortest and best position for his tunnel, with the conviction that however difficult from its altitude that position may be, he can attain it with ease, safety, and economy.

5. *Saving in the Length and Height of Viaducts.*

102. Viaducts and bridges are in general very costly, and this cost increases rapidly in proportion to the height of the structure.

103. The various modes of construction and material used must necessarily have a great influence on the cost, but this is in itself too large a question for present discussion, neither would it in any way assist the author to prove the saving his system claims to obtain for viaducts and bridges.

104. Fig. 10 represents an ordinary class of viaduct, carried on the level across a valley or other depressed section of ground, and at a considerable elevation.

105. Such a work would be very costly, owing to its height and length; but if the new system were adopted the cost might probably be reduced one-half, by the use of two gradients of 1 in 10, as shown on the diagram in dotted lines.

106. As shown in this diagram the advantages may seem questionable, but they must increase in proportion to the length of the viaduct.

107. The author particularly advocates this plan being resorted to for crossing over all depressed sections of country, especially when the width is great, and where great speed is not indispensable.

108. In all new countries, such as New Zealand and Australia, this method will effect very large savings, and not prevent the line at some future time from being brought up to the level, when the requirements of trade shall warrant the additional expense.

109. With reference to bridges, this system presents some obvious advantages, one of which is to allow the engine alone to cross the first span of the bridge, paying out its chain or rope until it has crossed, then continue to advance in this relative position to the train until the engine shall have passed over the whole length of the bridge, and then, without stopping, haul the train close up to itself.

110. The saving on the construction of the bridge may be proved in the following manner:—

111. Locomotives generally average from one-seventh to one-tenth of the weight of the train which they can draw at an average speed of 20 miles an hour on the level, and about only four times their weight up gradients of 1 in 80.

112. Their weight ranges to over 83 tons each, and this weight is distributed over about 15 feet length of roadway, or "*wheel base*," whereas the weight of the train may be distributed over probably 400 feet, or even more.

113. Thus it is evident that the passage of a locomotive over a bridge is more trying to the structure than the extra dead weight of the whole train equally distributed over its whole length.

114. Although it may sound absurd and bordering on temerity to talk of building a bridge which shall not be able at the same time to sustain both the engine and train, it still must be remembered that every bridge ought to be built in just proportions to the weight of the traffic it will have to sustain, which in practice is three times the weight it will ever be called upon to carry.

115. It seems, therefore, evident that the same strength or quality of material would not be required for the additional weight of the whole train.

116. Thus if these premises are correct, it is clear by all practical and theoretical rules, probably two-thirds of the strength would be sufficient for the girders, when the new system was used, and consequently a corresponding saving in cost of construction and material.

6. *Materially shortening all Lines which have High Land between their Extremities.*

117. To prove this advantage, it will only be necessary to refer back to the examples and arguments used to prove the first saving on surveys, and also the fourth example on tunnels.

118. These two examples, summed up in a few words, mean that any ridge of hills, or other elevated portion of country, may be crossed over or through with a far shorter length of

permanent way when adopting this new system, than can be done with the ordinary gradients now in use.

119. In further proof of the pecuniary advantage obtained and distance saved by the adoption of steep gradients, the author avails himself of certain facts which were printed by the Institute of Civil Engineers in 1867 :—

120. "For the passage of the Simplon from Bouveret to Arona, gradient 1 in 25, length 225 kilomètres, cost 156,410,000 francs; gradient 1 in 16, cost 130,410,000 francs; and gradient 1 in 12, cost 65,000,000 francs."

7. *A corresponding Saving in Length of Rails.*

121. The last saving of distance having been admitted to be correct in principle, this corresponding saving in the length of rails must necessarily follow.

122. The present high price of iron ought of itself to be a very strong inducement for the adoption of a system which promises such large savings in the item of rails alone.

123. It must also be remembered that if this first saving is effected it will make a corresponding saving in the subsequent repairs.

8. *Any Locomotive capable of hauling a given Weight up a Gradient of say* 1 *in* 50, *to be capable of hauling the same Load up* 1 *in* 10.

124. To prove this assertion it will be necessary to set down a few well-established facts relating to the known powers and performances of certain locomotives.

125. As an example, we will take one of Fairlie's light 26-ton locomotives, as constructed for the Patillos Railway in Peru.

126. With a tractive power or frictional resistance of 9230 lbs. (over 4 tons), it is clear that this engine would not have the least difficulty in ascending a gradient of 1 in 10 or even 1 in 8.

127. We will confine ourselves to 1 in 10, until practice shall have dictated the utmost limit to which it will be practicable or advisable to carry future gradients in combination with the new system.

128. With the above tractive force, we will assume that this

engine will take under ordinary circumstances a train weighing 60 tons up a gradient of 1 in 50, at a speed of 10 miles per hour.

129. On the level it will take it at the rate of 30 miles per hour.

130. It will therefore only be necessary to impart a hauling power of a little over 6 tons to the winding-drum, which it has been proposed to drive with a separate pair of cylinders.

131. This power can easily be obtained from the steam pressure direct, or there is no practical difficulty to increasing this hauling power by the use of gearing.

132. The actual arrangement of parts will become a simple matter of constructive detail, and must necessarily vary according to the construction of the locomotive which adopts the new system.

133. There can be little doubt that the speed of the drum can be regulated to give a hauling speed of 4 miles per hour.

134. Although at starting to haul the train the speed must be gradually increased from a state of rest, that speed may be maintained till within a few feet of the engine without danger of a concussion, as owing to the steepness of the gradient and the low rate of speed, the momentum of the train will be very slight.

135. For saving unnecessary loss of time in working this system, a great deal will depend on the judgment and active manipulation of the engineer in charge, who ought to turn on the steam to the engine cylinders and throw the drum out of gear the moment the train touches the engine, thereby taking advantage of the recoil of the buffers to assist the engine in making a start; for it must be remembered that by the automatic action of the struts attached to the train, it remains rigid whenever its forward motion ceases.

136. The author does not think any special length of chain or rope essential to the success of his system, and will in a great measure depend upon its weight and the capacity of the drum.

137. To combine strength and lightness a steel chain ought to be employed, and a chain offers the further advantage of being easily repaired by the introduction of spare shackles, notwith-

standing a steel-wire rope may claim advantages from its superior elasticity.

138. With the most ordinary care in starting the occurrence of a break ought to be seldom.

139. Thus it has been shown that the same engine which took its load up a gradient of 1 in 50 will take the same load up 1 in 10.

140. We must now compare the difference in the time consumed by the old and new systems in attaining a given altitude within a given distance.

141. The given length A B (Fig. 11) is one mile, and the given altitude 105 feet, giving a gradient of 1 in 50.

142. According to the old system, the engine with a train weighing 60 tons would accomplish the ascent, if at the rate of 10 miles an hour, in 6 minutes.

143. By the new system the engine and train would accomplish four-fifths of the distance on the level at the rate of 30 miles an hour, reaching the point C in 1 minute 36 seconds.

144. From C to A the length is only 1050 feet, giving a gradient of 1 in 10.

145. The engine will take the train up this incline, with a 150 feet length of chain, in 7 lifts, which will occupy 8 minutes, making a total of 9 minutes 36 seconds, being only 2 minutes 36 seconds longer than the old system.

9. *A much Lighter Class of Locomotive necessary.*

146. In reference to all locomotives, the laws which govern their tractive powers have already been explained.

147. As it is proposed with the new system to adopt comparatively light gradients or level wherever attainable, and then with the application of the new system, in one or more short but steep gradients, as shown in Fig. 11, the same weight of locomotive will not be required.

148. It is certain that any modern locomotive will carry "*itself*" up a gradient of 1 in 10, provided two-thirds of its weight is thrown on the driving-wheels, and the greater the number of these, the more certain and effective will be the result.

149. Therefore, suppose we reduce the weight of the engine from 26 tons to 16 tons, it will still be equally able to ascend the steep incline by itself.

150. This reduction in weight need not reduce the pressure of steam, consequently the power remains the same.

151. Therefore the lighter engine can still perform the same amount of haulage with the chain or rope.

152. This saving in the weight of the locomotive will in some degree effect a saving in its cost.

10. *A corresponding Reduction in Weight of Rails.*

153. What is it but the weight thrown on the wheels of a locomotive which governs the weight of the rails?

154 Having already shown how with this new system a much lighter class of locomotive will effect the transit of a load it could not do under the present system, it becomes evident that a much lighter class of rail will answer.

155. The unprofessional will hardly at first sight anticipate all the various indirect savings and advantages which this lessening in the weight of rails will effect.

156. As it is one of the chief commercial advantages which the new system offers, it is proposed to allude briefly to some of them.

157. There is the difference in the first cost; where the new system would use rails weighing from 40 to 50 lbs. to the yard, the old or present system would require 70 lbs. at least, and probably more than that if gradients of 1 in 50 were attempted.

158. Now it must be remembered that, as the steepest or "*ruling gradient*" on all railways determines the "*weight*" of the locomotive required to draw a given load at a required speed up that gradient, so does the "*weight*" of the locomotive determine the "*weight of the rails along the whole line.*"

159. A further and consequent saving will follow in the first laying down of the lighter rails, less ballast will be required, and also lighter sleepers.

160. Then there is the transport of the rails. As many

countries which do not supply their own rails are making railways, it often becomes a serious question for the contractor to know how he is to transport by sea such an awkward freight as rails in sufficient quantity to keep pace with the requirements of his contract, for each ship can only take a certain proportion of dead weight in accordance with her tonnage.

161. That delays have occurred from this cause may be gathered from a circumstance which occurred within the last year.

162. During one of the debates of the New Zealand Parliament, the Government were asked, "How it was, that Mr. Brogden was not proceeding as fast with his railway contracts as promised?" The answer was, "*The Contractors were at a stand for rails, but that more were being shipped from England as fast as vessels could be obtained to carry them.*" Of course the vessels here alluded to were being laid on for New Zealand with general cargo, as it would never have paid to freight ships to New Zealand with rails alone.

163. Thus any considerable reduction in the weight of rails will reduce the cost of transit.

11. *Simplicity of Construction inexpensive and not easily deranged.*

164. Hardly any more simple and less inexpensive piece of machinery could be added to a locomotive to produce the great and varied advantages which are expected to be derived from it.

165. As it has already been fully described, it will be seen to be of a nature not easily deranged.

12. *Less Friction and Tear and Wear, &c.*

166. If we consider the ratio in which friction or tractive force is required from the engine, in proportion as the gradient increases, when hauling a train after it, it will appear evident that the new system must necessarily save a large amount of this friction or grinding of the rails, as by it the engine will only have to provide sufficient tractive adhesion to carry itself only up the gradient.

167. As regards tear and wear, it having been already ad-

vanced that "*lighter locomotives*" will suffice, the rails will not have to sustain the same amount of crushing weight which, under the present system of weighty engines, renders the renewal of the best class of rails frequent, and consequently one of the largest items in the subsequent expenses of a line.

168. It must also be remembered that "*light rails*" wear longer in proportion than "*heavy ones*," from this simple reason, that the extra "*weight*" and "*strength*" do not in the least improve the "*quality*" of the iron, and that the power of the metal to resist compression remains the same, whether in a heavy or light rail.

169. Therefore the heavier engine will destroy its rail much sooner in proportion than the lighter engine will its rail, as adapted to its weight.

170. No one can doubt this who has seen the way in which the heaviest class of rails are blistered and splintered by the crushing engines they are called upon to carry.

171. A lighter class of engine cannot fulfil the requirements of business on account of the existence of comparatively light gradients along the line, and where a certain speed must be maintained.

172. Consequently, the steeper the gradient is which has to be overcome by the ordinary means in use, the "*heavier*" must the engine be made, and thus the greater tear and wear of the rails.

13. *No Break of Gauge necessary, and applicable to any Gauge.*

173. It will be generally admitted by those who have read the foregoing description of the new system that gauge has nothing to do with it.

174. From this fact it is hoped to be able to secure the goodwill and co-operation of the advocates of all gauges, and there is little doubt that the various gauges now in operation all over the world are doing much to settle the question which gauge will be eventually recognized as the most useful and economical.

175. It may also be found expedient to graft this new system on to existing lines, to which there is no obstacle whatever.

14. *Especially applicable to Tramways, which, as Feeder Lines, will often penetrate into Hilly Districts.*

176. By the term tramway is meant a light class of railway for locomotive traffic.

177. It is not pretended to claim any direct advantage to existing lines of railway from the adoption of this system, as their gradients are both too steep and not steep enough to fulfil the first requirements to the success of the system.

178. Existing lines have been taken hitherto along the best line that could be selected, with the chief end in view of avoiding steep gradients.

179. Consequently, as main trunk lines they must fulfil their destiny; but feeders may be required, and when these are taken into mineral districts, which are generally very hilly and broken, then the new system may claim careful consideration from those who contemplate making such lines.

15. *The Carrying Power along the whole Line not limited by the frequent Occurrence of Steep Inclines.*

180. Under the present system this limit does exist to a most tyrannical degree; thus we shall suppose that an engine leaves a certain station with a given load which it can take with ease so long as the gradients are very slight; but, on meeting with a gradient of say 1 in 50, it is perfectly unable to proceed, and a portion of the train must be left behind or another engine added; thus the carrying power of this one engine is limited by the occurrence of such gradients.

181. In America, on the Central Pacific line, three engines are frequently used, two in front and one behind, for taking the heavy goods trains up the several steep inclines with which the line abounds.

182. Here, then, is evidently a waste of power; not that all this tractive force is not required to take those trains up the gradients, but that it was so much surplus power not required when descending, or on comparatively level portions of the line.

183. It may be said that these extra engines are only added when these special gradients occur; but still the extra engines

have to come down again; and therefore why use any extra engines at all, when one carries within itself ample power, if worked with the new system, to overcome greater gradients than have been contemplated under the ordinary means of traction?

184. So far it has been endeavoured to prove the fifteen advantages claimed for the new system.

185. But there are a few additional points bearing on the subject, and which have not yet been alluded to, and which may suggest themselves to many who have read this paper.

186. The first in importance is the safe "*descent*" of such steep gradients as 1 in 10.

187. From the highly satisfactory way in which the patent air-break is worked on the American lines, there can be little doubt of its fulfilling all requirements of safety.

188. At the same time it must be remembered that, as a rule, such steep gradients as 1 in 10 will seldom be of great length, for the simple reason that a long gradient with such an incline would attain an elevation seldom required.

189. But if required, then there is no reason against the long gradient being cut up into as many short gradients as desirable, with any desired length of level between each, to prevent danger from too great an acceleration of speed.

190. By this arrangement the ascent will be made with a succession of steps.

191. Referring to the air-break, it is simple, equally applicable to every wheel in the train, and under the instantaneous control of the engine driver, who can at will apply as much check to every wheel in the train, as well as to his engine and tender, as required, even to locking dead.

192. At a special trial of these breaks, it was proved that any train running at the rate of 40 miles per hour was brought to a stand within a distance of 370 feet.

193. If, however, there should still exist any doubts of the sufficiency of checking power to be derived from the air-break, it is well to know that a far more powerful break does exist.

194. It is the invention of Mr. Brunlees, and has already been successfully applied by that gentleman to an existing line, the São Paulo inclines in Brazil, which are 1 in 10.

195. The author takes this opportunity of thanking, and considers himself greatly indebted to, that gentleman for the encouragement he gave regarding the merits of the invention.

196. This break consists of a clip, which at will can be lowered down on to the rail, and then made to grip the top sides of the rail with any degree of power, even to locking dead.

197. One of the great advantages of this break is that the friction, and consequently wear, is derived from that portion of the rail, "*the sides*," which never have to sustain the wear of traffic.

198. The question of starting a train is one of no little importance, and its results have a good deal to do with the economy of working expenses.

199. Heavy engines are used for passenger trains in proportion to the weight of those trains, otherwise the required speed could not be maintained over the ruling gradients of the line, consequently the starting of these trains is comparatively easy.

200. Not so is the rule with goods trains, which are generally loaded up to the full power of the engine.

201. To enable these trains to start, the wagons are coupled very loosely together, so that at starting each truck advances consecutively at least four inches before pulling the next truck, thus the engine gets the start of several feet before it feels the weight of the last truck.

202. Although this arrangement does enable the engine to start, it is done at the expense of a succession of jerks, which are very injurious to the couplings and frames of the trucks.

203. Another evil resulting from the loose coupling, is the liberty the trucks have to oscillate when going at a high rate of speed, thus causing the flanges of the wheels to grind heavily against the rails, and thereby not only causing unnecessary wear and tear to rails and wheels, but also throwing a considerable amount of unnecessary work on the engine.

204. So great is the resistance produced by this oscillatory motion of the trucks, that it has been proved that a train of loaded coal wagons will not descend a gradient of 1 in 75 of their own accord.

205. By the adoption of the new system all these evils may

be remedied, for the trucks may be coupled close, and then the engine advancing a few feet without them, gives to all of them the required momentum, with its chain or rope, and then proceeds with this advantage.

206. In going round any sharp curve the same advantage may be secured. It is generally after the engine has passed the sharpest part of the curve that the train commences to jam on it, and a very short distance would suffice to place the train past the difficulty.

207. This new system may recommend itself to the notice of railway and other contractors, offering as it does an easy and economical method of moving material.

208. This system may also be applied to military operations, where the object is often to construct a temporary railway with the utmost expedition for the conveyance of heavy ordnance, and other military stores, to the scene of action.

209. It may also be made available in trench work, which as a rule is on a sharp ascent.

210. By adopting this system, many natural inequalities of the surface of the ground may be surmounted without even breaking the surface, whereas if adopting the ordinary system heavy cuttings and embankments would be required.

211. Owing to the numerous collisions which have lately taken place on our English lines, caused in a great measure by the different speeds at which express, passenger, and goods trains are obliged to run, it appears that ere long some special means will have to be resorted to for the prevention of the melancholy waste of life and property that has been recurring for some time past.

212. It is even probable that public opinion may become sufficiently urgent on this point to render special legislation necessary.

213. Then must follow the question of what means are to be universally adopted for the prevention of the evil.

214. The one which naturally suggests itself is the laying down of another double line of rails for the sole use of the goods traffic.

215. If such were the means adopted, the author is of opinion

that the new system would be of great economical service in carrying out this plan, for although in many places it may be advisable to adhere to the side of the existing line, still there are often those portions of the line which present the expensive engineering obstacles already alluded to.

216. It is for the overcoming of such that the new system will be found both economical and effective.

217. In many cases it will even be found advisable to leave the side of the existing line, and by either ascending or descending some steep gradient, a considerable saving in "*length*" of permanent way may be obtained.

218. In proof that these sentiments are already being publicly expressed, the author takes the liberty of quoting from a letter which appeared in 'The Times' of December 25th, 1873, by G. W. Grover, M. Inst. C.E.:—

219. "Then comes the question whether it would not be better to make new lines, independent of the existing ones and a certain distance from them, so as to open up new lines of country? To this it may fairly be said that such lines would seldom pay if they were to be constructed on the standard system; and although they certainly might have the effect of relieving the traffic on the main arteries, they would form a source of burthen and expense to their constructors. Hence we are driven to the conclusion, that something is wanted of a simpler and handier nature than is at present obtainable. The main lines require relieving, and the landowner requires increased facilities. The highways have been made, and now we want the byeways. This only can be accomplished by abandoning at once and boldly the preconceived notions of a railway's existence, and developing a system of light and cheap tramways following the contour of the ground, and going round hills and not through them."

220. In 1870 Mr. Brunlees, when giving his reason for adopting the steep gradients on the São Paulo Railway, said:—

221. "That, although a little less coal might be consumed by using a locomotive gradient of 1 in 40; that was, however, a small matter when compared with the fact that the interest on the additional capital necessary for a locomotive line would alone have amounted to about 200*l*. per day."

222. In corroboration of this statement we have the estimate of Mr. Lane, the Brazilian Government Engineer-in-Chief, that

223. "A locomotive line up the Serra would cost mile for mile as much as the inclined road, and this would be 2,000,000*l.* for a locomotive road, as compared with 500,000*l.* the cost of the inclined road."

224. And again, in connection with the Dom Pedro Segundo Railway, in Brazil, where the locomotive gradients are 1 in 33, the engineer of that line, Major Ellison, has been heard to say:

225. "That if he had again to go through that description of country, he would get over the difficulty by means of inclines, rather than by prolonging the works to get a locomotive line."

226. The actual saving by the use of "*rope traction*," when properly applied, in comparison with ordinary locomotive traction, was very clearly stated by Captain Tyler, in 1867, before a meeting of the Institute of Civil Engineers, that—

227. "The incline of the Taff Vale Railway, 16 miles from Cardiff, averaging 1 in 20, had at first been worked by a rope, which was replaced by locomotives weighing 36 tons, which took an average load of 25 tons; these had been abandoned and the rope traction resumed, showing the following result:— Six months expenses of working locomotive, 900*l.*; rope, 700*l.*"

228. On the same occasion Mr. Hemans quoted the following statement, made by Mr. C. R. Drysdale:—

229. "That the total cost of working an incline on the Edinburgh and Glasgow Railway for one year was 734*l.* 18*s.* 4*d.*, when the traffic was worked with a wire rope by a stationary engine, and 3204*l.* 16*s.* 10*d.* when locomotives were used, giving a difference of 2460*l.* 18*s.* 9*d.* in favour of the wire rope system."

230. The foregoing instances clearly prove and indicate the commercial advantages of the rope system, even when applied to a gradient which can be worked by locomotives; how much greater, then, must that advantage become when it is able to be applied to any number of steep gradients which may occur along a line, without in any way interfering with the ordinary construction of permanent way, requiring but a small addition to the mechanism of rolling stock, and dispensing with the

addition of stationary engines, involving all the expense and frictional wear entailed by guide-rollers and long and weighty ropes.

231. The author hopes that the subject-matter of this paper may prove of some interest, and worthy of consideration, not only at the hands of the professional world, but to the public at large, whose interests are so intimately associated with the economical extension of the already vast railway system of this country, and also with the creation of new lines all over the world.

232. The author would be glad to have the opinions and criticisms of professional men, regarding any flaws they may fancy exist in the theory of his system; and at the same time invites the assistance and co-operation of engineers and capitalists in bringing this new system into use, not only in England, but more particularly abroad, where great speed is not considered so essential as in this country.

233. In conclusion, the author will gladly give any further information and details to any who may wish to become better acquainted with the merits of his system, and invites such to inspect his plans and working model, which to the unprofessional will show that thorough proof of the capabilities and practicability of the system which no mere description can convey.

234. All communications addressed to the author will receive immediate attention.

Henry Handyside,
26, Alma Square, Abbey Road,
London, N.W.

February, 1874.

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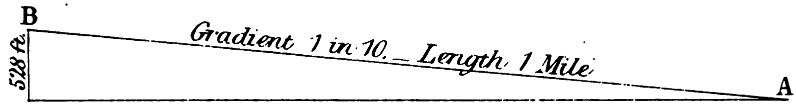
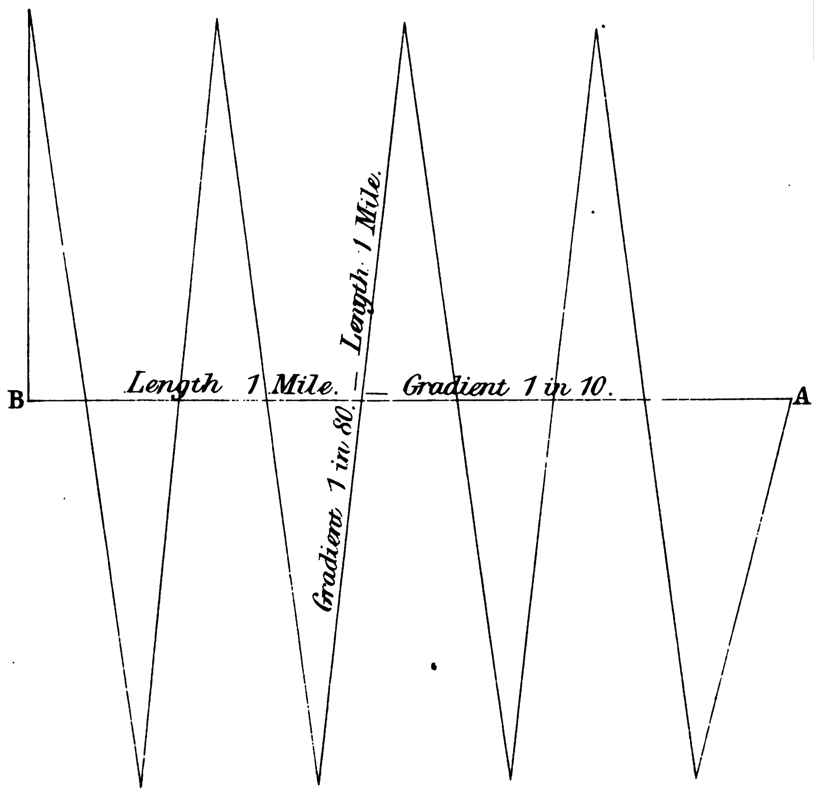
Fig. 5.



ELEVATION.

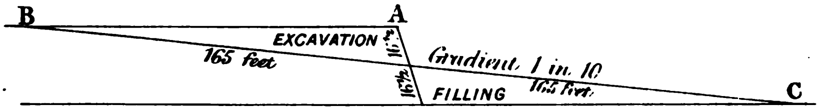


PLAN.

Fig. 6.

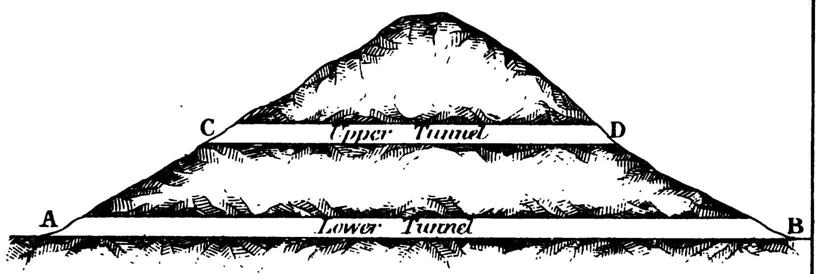
ELEVATION.

Fig. 7.



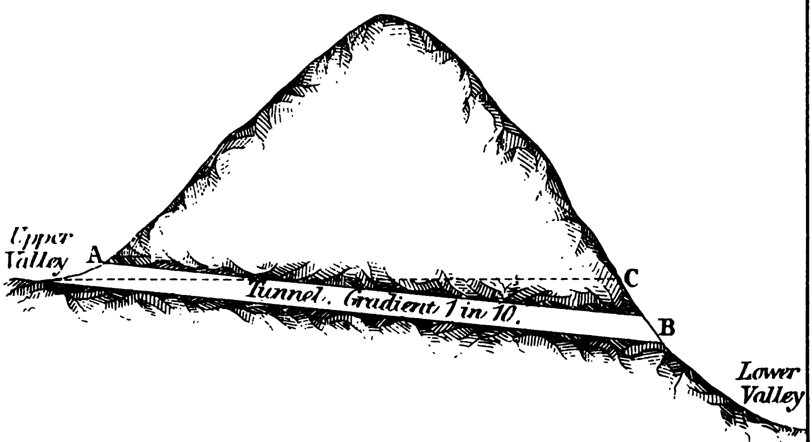
SIDE ELEVATION.

Fig. 8.



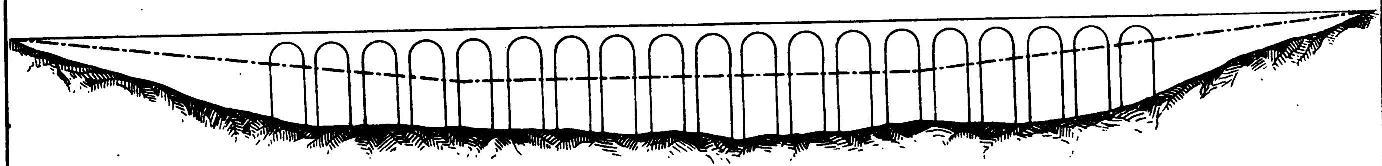
SECTIONAL ELEVATION.

Fig. 9.



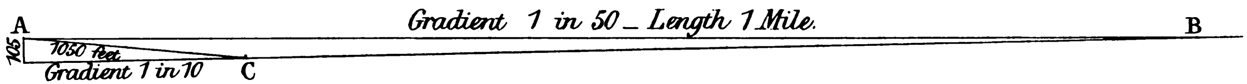
SECTIONAL ELEVATION.

Fig. 10.



SIDE ELEVATION.

Fig. 11.



SIDE ELEVATION.